Weed Control in Bareroot Hardwood Nurseries

David B. South
William A. Carey

David B. South is Professor, School of Forestry and Wildlife Sciences, Auburn University, AL 36849-5418; telephone: 334.844.1022; e-mail: southdb@auburn.edu. William A. Carey, deceased, was Research Fellow, School of Forestry and Wildlife Sciences, Auburn University, AL.

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Abstract: Managers in the southern United States rely on chemical and non-chemical methods of weed control. Chemical treatments include fumigation with methyl bromide and chloropicrin in combination with selective herbicides. If methyl bromide is no longer produced in the future, the amount of handweeding will likely increase unless managers adapt to the change. Some nursery managers will increase use of both sanitation practices and herbicides. Although several herbicides are registered for use on hardwoods, some formulations can injure seedlings if applied to seedbeds. Grasses can be effectively controlled with selective herbicides and many small-seeded broadleaf weeds can be suppressed with preemergence herbicides. Several nursery managers have fabricated shielded herbicide sprayers to apply herbicides between drills.

Keywords: herbicides, fumigation, integrated pest management

Introduction

Hardwoods grown in southern forest nurseries represent approximately 4% of the total seedling production. Less than half of the forest tree nurseries in the South grow hardwoods. In 2002, total production from hardwood nurseries was less than 50 million seedlings (McNabb and VanderSchaaf 2003). However, on an area basis, a hardwood crop is more valuable than a pine (*Pinus* spp.) crop. One hectare (2.5 ac) of hardwoods typically produces about 440,000 seedlings (each worth about U.S. $0.30 each). This amounts to a crop value of over U.S. $130,000/ha (U.S. $52,000/ac).

Oaks (*Quercus* spp.) account for more than half of the hardwood production (Table 1). Other large-seeded species include hickory (*Carya* spp.), pecan (*Carya illionensis* [Wangenh.] Sarg.), and black walnut (*Juglans nigra* L.). Small-seeded species include yellow poplar (*Liriodendron tulipifera* L.), green ash (*Fraxinus pennsylvanica* Marsh.), cottonwood (*Populus deltoides* Bartr.), sycamore (*Platanus occidentalis* L.), sweetgum (*Liquidambar styraciflua* L.), and dogwood (*Cornus florida* L.).

Developing herbicide programs for individual species such as black walnut can be difficult because relatively few seedlings are produced. Due to the high crop value of hardwoods, several managers prefer that herbicide screening tests be limited to pines. For these reasons, weed control research in hardwood seedbeds has concentrated on developing herbicide programs that are suitable for most hardwoods. Without herbicides, handweeding in hardwood seedbed might exceed 500 hr/ha (200 hr/ac). Although a nursery may grow only a few hectares of hardwoods each year, handweeding times might exceed that for a much larger area of conifers. For example, untreated hardwood seedbeds at one nursery required more than 3,900 hr/ha (1,560 hr/ac) of handweeding (Abrahamson 1987). When combining soil fumigation with herbicides, hardwood seedbeds now require only 60 to 250 hr/ha (24 to 100 hr/ac) of handweeding.

Management Practices

Efficient weed management systems for hardwoods involve a combination of methods which may include sanitation, living mulch, fumigation, and herbicides. Less efficient systems usually rely on just 1 or 2 methods of weed management.

Table 1—Hardwood seedling production from nurseries in 2002 (McNabb and VanderSchaaf 2003).

Group	Bareroot	Container	Total
Oaks	27,325,800	171,100	27,496,900
Green ash	2,621,500	7,000	2,628,500
Yellow poplar	1,282,800	14,000	1,296,800
Dogwood	892,900	8,000	900,900
Pecan	892,000	0	892,000
Sycamore	782,000	7,000	789,000
Sweetgum	638,200	3,000	342,200
Black walnut	508,000	0	508,000
Cottonwood	320,000	0	320,000
Others	11,849,000	33,400	11,882,400
Total	47,112,200	243,500	47,355,700

Sanitation

Sanitation is an important component of an effective weed control program (Wichman 1982). For this reason, it is important to prevent the introduction of weed seeds in composts, mulches, seeds, and irrigation water. Composts were used in the past to increase soil fertility, but they were a source of weed seeds. Adding leaves from lawns or municipal sludge to the soil can also introduce weeds. Therefore, composts are typically not used in hardwood seedbeds.

Weed seeds can be present in mulches such as pine straw, wheat straw and, in some situations, sawdust. During the 1950s, pine straw was the favored mulch at many hardwood nurseries, but it often introduced a significant amount of grass seeds (South 1976). Today, several hardwood managers use weed-free, polyethylene soil stabilizers instead of straw mulches.

Several nursery managers use certified seeds for cover-crops to reduce the introduction of noxious weeds. Regulations require certified seeds to be free of primary noxious weed seeds and only small amounts of common weed seeds are allowed. Several managers sow cover-crops at densities that keep soil shaded to suppress weed growth. In particular, nutsedge (*Cyperus* spp.) competes poorly when shaded by dense cover crops.

Irrigation water can be a major source of weed seeds, especially when pumped from lakes, ponds, or rivers. For this reason, several nurseries use in-line screens to filter weed seeds. Some of the newer filter systems are self-cleaning.

Weed seeds, rhizomes, and tubers are easily introduced to a nursery on farm equipment that is rented or borrowed from adjacent landowners. For this reason, some managers thoroughly clean rented combines before harvesting cover crops. Some managers avoid this potential weed source by not harvesting corn (*Zea mays* L.).

Mechanical Cultivation

Since the drill spacing within a seedbed is often 30 to 60 cm (12 to 24 in), mechanical cultivation is more feasible than in most pine seedbeds (South 1988). At one nursery, mechanical cultivation reduced handweeding requirements by 21 hr/ha (8.5 hr/ac) (Barham 1980). Although reductions in weed densities can be achieved by mechanical cultivation (South 1988), most hardwood nurseries in the South rely on other weed-control practices.

Living Mulch

The concept of a "living mulch" was introduced into the South by the Virginia Department of Forestry during the 1980s. Rye (*Secale cereale* L.) seeds were drilled into the sections immediately before sowing white pine (*Pinus strobus* L.) and hardwoods in the fall. The "living mulch" protected the fall sown seedbeds from injury by wind, rain, and frost. This system was also effective for fall-sown hardwoods in Illinois and Indiana (Stauder 1993; Wichman 1993). Nursery managers in Georgia and Tennessee currently use this system on fall-sown hardwoods (Ensminger 2002). Wheat (*Triticum aestivum* L.), rye, or oats (*Avena sativa* L.) is sown on prepared beds before fall sowing acorns. The grass mulch is sprayed with glyphosate in February prior to emergence of oak seedlings. This system provides several advantages, including a retardation of weed growth.

Fumigation

It is relatively easy to justify soil fumigation, which typically costs less than 2% of the value of the hardwood crop. For this reason, most hardwood managers in the South fumigate the soil prior to each hardwood seedling crop. Although dazomet is used in northern hardwood nurseries (Schroeder and Alspach 1995; Storandt 2002), hardwood managers in the South have relied on methyl bromide/chloropicrin fumigation to reduce pest populations. One advantage of methyl bromide/chloropicrin is that it can be used relatively close to fields containing seedlings. In some situations, injury to adjacent crops has occurred when dazomet or metham sodium was applied without a tarp (Scholtes 1989; Buzzo 2003).

Few hardwood nurseries have problems growing endomycorrhizal crops after fumigating with 98% methyl bromide (Campbell 1992). So far, fumigation tests with 336 kg/ha (300 lb/ac) of chloropicrin have not detrimentally affected sweetgum or oaks. Methyl bromide fumigation that included chloropicrin at 129 to 168 kg/ha (115 to 150 lb/ac) has occasionally reduced growth of some species (for example, sweetgum and dogwood). This was due to a deficiency of endomycorrhizal inoculum (South and others 1980). In fact, in 1994, one nursery in Georgia had stunted corn due to effective fumigation with 33% chloropicrin and 66% methyl bromide. Some managers may use other fumigants such as dazomet or 1,3-dichloropropene for beds to be sown with dogwood or sweetgum.

In the future, methyl bromide will continue to be produced by oceans, fires, plants, and fungi. However, it is possible that in the future, it will no longer be used as a fumigant due to restrictions on production. If this turns out to be true, some managers will likely switch to fumigants that are relatively weak on weeds. Possible alternatives include chloropicrin and dazomet. Although both can control certain soil-borne pests, neither is as effective in controlling nutsedge as methyl bromide (Carey 1995; Carey and South 1999; Fraedrich and Dwinell 2003).

Herbicides

To control weeds without injuring hardwood seedlings, the herbicide must either be selective (such as fluziflop-butyl; see Table 2 for common names) or it must be applied in a manner that avoids seedling injury. Selectivity is based on physiological or morphological differences between crop and weed. For example, a physiological difference between broadleaves and grasses is the basis of selectivity for sethoxydim and for fluziflop-butyl. As a result, handweeding grasses should no longer be necessary. Many annual broadleaf weeds can be controlled with other herbicides (South and Gjerstad 1980; South 1984, 1992; Porterfield and others 1993; Altland and others 2003).

Morphological differences between crop seeds and weed seeds can be used to provide some selectivity. Large-seeded species such as oak, walnut, pecan, and hickory tolerate preemergence herbicides that might kill small-seeded species. For example, oxyfluorfen can be applied after sowing without injury to walnut, pecan, hickory, and oak.

Differences in plant size can also influence selectivity. Some herbicides (like trifluralin, oryzalin, prodiamine, and napropamide) are active mainly on seed germination. These herbicides can be applied once hardwood seedlings have germinated and have developed a few true leaves. The herbicides can be toxic to small hardwood seeds, such as sycamore, if applied at time of sowing. When applied after the seedlings are established, the chance of injury is greatly reduced. Although these herbicides do not control emerged weeds, they will help keep subsequent weed seeds from germinating. This technique is used successfully by several nursery managers in the South.

With some herbicides, formulation affects selectivity. Formulating herbicides as granules is a common practice to reduce injury. When applied to dry foliage, herbicide granules of oxyfluorfen and oxadiazon are less phytotoxic than liquid formulations. Herbicide injury still occurs if granules lodge in the foliage or are not completely washed off with irrigation. Therefore, it is important for most granules to be applied to dry foliage. At some nurseries, irrigation is applied immediately after treatment to increase selectivity.

Although granular herbicides are commonly used in container nurseries that produce horticultural plants (Everest and others 1998), bareroot nurseries rarely use granular herbicides. Although effective weed control can be obtained with granular herbicides (Reeder and others 1992), many managers apply cheaper liquid formulations as broadcast sprays. For example, 1 kg (2.2 lb) of napropamide might cost U.S. $13 as a powder and U.S. $100 as a granular formulation. A partial list of trade names of granular herbicides used in ornamental container nurseries is provided in Table 2.

Selectivity can be increased by avoiding contact to crop foliage. This can be done with either using hand-held equipment or by using shields to apply herbicides between drill rows (Figure 1). Most foliar active herbicides should be directed away from the crop and toward the weeds. A number of nursery managers have fabricated equipment to apply glyphosate to weeds between seedling drills (see Stallard, this proceedings; Vachowski, this proceedings).

A final way to provide selectivity is to apply the herbicide to the cover-crop instead of treating the hardwood crop directly. For example, some nursery managers sow Roundup Ready® corn and then spray glyphosate to kill nutsedge and troublesome annual weeds. There are several new herbicides that are registered for use on cover crops (Webster 2003) but are not legal for use on hardwood seedbeds.

Table 2—Common names, trade names, and manufacturers of selected herbicides.

Trade name	Common name	Company
Selective grass herbicides		
Acclaim®	Fenoxaprop-ethyl	Bayer
Fusilade® II	Fluazifop-butyl	Syngenta
Vantage®	Sethoxydim	BASF
Envoy®	Clethodim	Valent
Selective herbicides		
Barricade®	Prodiamine	Syngenta
Dacthal®	DCPA	Amvac
Devrinol®	Napropamide	United Phosphorus
Treflan™ 4EC	Trifluralin	Monterey
Pennant® Magnum™	Metoalochlor	Syngenta
Granules		
BroadStar™	Flumioxazin	Valent
Devrinol® 2G	Napropamide	United Phosphorus
Ronstar® G	Oxidiazon	Bayer
Rout®	Oxyfluorfen+oryzalin	Scotts
OH2®	Oxyfluorfen+pendimethalin	Scotts
Regal O-O®	Oxyfluorfen+oxadiazon	Regal
Pendulum®	Pendimethalin	BASF
Non-selective		
Basagran® T/O	Bentazon	BASF
Finale®	Glufosinate-ammonium	Bayer
Roundup Pro®	Glyphosate	Monsanto

Figure 1—A directed herbicide sprayer for hardwood seedlings at the East Tennessee Nursery.

Treatments Used by Managers

Commonly used herbicides were determined by surveying 14 hardwood nurseries. Methyl bromide/chloropicrin fumigation was used at all of the nurseries. To suppress hardwood diseases and to reduce the consumption of methyl bromide, several managers used methyl bromide with 33% chloropicrin.

Half of the nursery managers (7) used no herbicides at time of sowing. Some were afraid that herbicides could result in seedling injury. Five nurseries had good results in tests of oxyfluorfen on large-seeded species such as oaks, persimmons (*Diospyros virginiana*), and hickories. One nursery applied EPTC as a pre-sow, soil-incorporated treatment. Trifluralin was used after sowing at 2 nurseries.

Managers at 13 nurseries used postemergence herbicides (applied postemergence to the crop). Selective grass herbicides were the most popular. Sethoxydim was used at 8 nurseries and 7 nurseries used fluzifop-butyl. One nursery applied the granular herbicide Rout® to a limited amount of emerged seedlings.

Napropamide was applied postemergence to the crop at 6 nurseries and prodiamine was applied in a like manner at 4 nurseries. These herbicides can be applied to seedbeds after germination of hardwoods is complete (South 1984, 1992). These herbicides do not have contact activity and therefore are not generally phytotoxic to emerged seedlings or weeds (Skroch 1994; Everest and others 1998).

Glyphosate was used as a directed spray (Figure 1) at 5 nurseries as needed to weeds that were tolerant of other herbicides. Several nurseries have constructed shielded applicators to apply glyphosate between seedling drills.

Managers at 6 nurseries apply a soil stabilizer after sowing hardwoods. Rates vary depending on season, soils, rainfall patterns, and budgets. One manager applies 1,122 l/ha (118 gal/ac) of Agrilock® over fall-sown beds (over sawdust mulch) while 561 l/ha (59 gal/ac) are applied after sowing in the spring (with no sawdust mulch). Two managers used rates as low as 330 l/ha (35 gal/ac).

Comments by Managers

The following edited comments are from 9 nursery managers:

1. Cover small seeds with mulch or soil at the time of sowing (especially when treating with a soil stabilizer).
2. Trifluralin (applied just after sowing) caused some damage to sycamore.
3. No problems were encountered with sethoxydim or trifluralin. Oryzalin slightly damaged dogwood, sycamore, sweetgum, and maple (*Acer* spp.). OH-2® injured deciduous magnolias (*Magnolia* spp.), maples, dogwood, and sweetgum.
4. Soil-incorporated EPTC, applied 30 days before sowing in the spring, does not seem to have any effect on seedlings. We also have treated soil in fall before sowing in spring.
5. Oxyfluorfen applied as a postemergence herbicide to oaks, and watered in immediately, causes some slight burning, but does not have any long lasting effect on the seedlings.
6. Pendimethalin at sowing gives good control in oaks and pecan.
7. Metolachlor applied as a preemergence herbicide (after sowing) slows the germination of white oak and sawtooth oak, but has little noticeable effect in water, willow, cherrybark, Nuttall, or Shumard oaks.
8. Metolachlor applied as a postemergence herbicide to hardwoods slows the growth of seedlings a little, but not adversely so.
9. Oxyfluorfen can be used on large-seeded oaks, persimmons, and hickories. A surfactant rather than oil should be used when using sethoxydim or fluziflop-butyl. Using a crop-oil can damage hardwoods. Shrub lespedeza (*Lespedeza thunbergii* (DC.) Nakai) can be treated with 2,4-D amine.
10. Sethoxydim should be applied before (not after) top-pruning oaks.

Conclusion

Due to the numerous species involved, a single herbicide regime is unlikely to be effective for all hardwood species. South (1995) proposed a regime that could be adapted for a variety of hardwood species. A regime of this type should be used in conjunction with a rigorous sanitation program. The regime relies on use of a selective grass herbicide (for example, fenoxaprop-ethyl, fluazifop-butyl, sethoxydim) in conjunction with a few other herbicides (napropamide, prodiamine, oryzalin) to control germination of small-seeded broadleaf weeds. Oxyfluorfen can be used for large-seeded field-grown ornamentals. Nutsedge is controlled with glyphosate on fallow land (South 1979; Fraedrich and others 2003) while emerged weeds are controlled with either handweeding or directed applications of glyphosate or glufosinate-ammonium. Due primarily to a difference in herbicide use, some claim that weed control in bareroot seedbeds is now easier than controlling weeds in container nurseries (McRae 1999).

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